U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 132

Backscatter Ultraviolet (BUV) Ozone Analysis System

R. M. Nagatani, J. D. Laver, and A. J. Miller
Development Division

MARCH 1977

This is an informal unreviewed manuscript primarily intended for the exchange of information among NMC staff members.

Within the recent literature there has been considerable concern expressed on the possible anthropogenic influences on the atmospheric ozone amount and its subsequent impacts on climate, the biota and man. Until now a major difficulty in assessing the actual ozone trends, as well as depicting the dynamic and chemical interactions, has been the lack of spatial coverage of the data.

In April 1970, the Backscatter Ultraviolet (BUV) Ozone measuring system was launched on-board the Nimbus 4 spacecraft. The purpose of this experiment is to determine both total ozone and the ozone distribution in the general region 25-55 km (above the concentration maximum) on a global scale. Various authors have described the BUV system and comparisons with other data (e.g., Mateer et al., 1971; Heath et al., 1973). Basically it appears that the total ozone values compare to the Dobson information to within about 5% and the mass mixing ratio results are within about 15% of the ozone rocketsonde information.

As part of the overall analysis procedure, the Upper Air Branch, NMC, has entered into a cooperative agreement with NASA, Goddard Space Flight Center, whereby the ozone data are subjected to synoptic type analysis. These analyses are then merged with appropriate meteorological analyses to provide information on the global climatology of ozone, its transport by the wind fields and its general relationship with meteorological factors. Our purpose here is to describe briefly the synoptic analysis system employed on the ozone information and to cite examples of the results.

Table 1 depicts the current ozone analysis products. As noted, the Northern Hemisphere analyses consist of both total ozone and ozone mixing ratio at 30, 10, 5, 2 and 0.4 mb, but the Southern Hemisphere is restricted to total ozone only. This is due to the South Atlantic radiation anomaly which increased the noise level of the upper level retrievals in the Southern Hemisphere. It is anticipated that this difficulty will be resolved in future instruments, permitting reasonable analyses in both hemispheres.

As the BUV instrument is a non-side scanning type and as observations are restricted to daylight hours only, it became necessary to include data for 2 days into each analysis. Thus, only analysis products for 2 full days, i.e., days 1-2, 3-4, 5-6, etc., are available.

In Figure 1 is shown a typical data field for one two-day period. We note that the coverage is quite extensive, but two major features should be emphasized. The first is that in the Alaska region there is a consistent loss of data as this is the satellite readout area. Second, for the winter period the nighttime terminator is encountered at about 65°N and, thus, the data are restricted to below that latitude. As the seasons change and the latitude for the northernmost data points increases, these points are incorporated into the analyses.

The BUV ozone data used as analyses input are available on magnetic tape in sequential orbit numbers. Within each orbit is a sequence of observations with identifiers for day, hour, minute, latitude and longitude. The parameters available at each location include total ozone (atm-cm) and mixing ratio (μg/g) at 0.4, 0.5, 0.7, 1, 1.5, 2, 3, 4, 5, 7, 10, 15, 20, 30 and 40 mb. As indicated previously, the Upper Air Branch has selected the following parameters for analysis in the Northern Hemisphere: total ozone, and mixing ratios at 0.4, 2, 5, 10 and 30 mb. Data with path lengths greater than 9 are not used to avoid problems at the winter terminator. Although some quality control checks were performed on the data, it has been necessary to establish variable gross toss-out limits to filter out the remaining suspect data prior to executing the analysis program. These limits may be made a function of season in future analysis series. Performing analyses on 48-hour segments of data results in 400-500 data points per analysis depending on season, instrument problems, etc.

The analysis technique employed is based on the adjustment of a first guess field toward the data and, as such, the initial creation of a reasonable first guess field at evenly spaced gridpoints is critical to the procedure. The analysis grid is an NMC standard one consisting of a 47 x 51 rectangular array representing a polar stereographic projection with gridpoints spaced at 381 km (true at 60°N). With point (1,1) beginning at the lower left of a rectangle and "I" and "J" representing columns and rows respectively, point (I,J) = (24,26) represents the pole. Orientation is such that meridians 80°W and 100°E fall along column 24. (See Figure 2.)

First guess values at gridpoints (for each parameter) are derived from mean values of reported data over 15° latitude bands. To avoid discontinuities in the guess field, a linear interpolation, based on the actual latitude of the gridpoints, is performed between the latitude bands, Due to the northern termination of daylight, winter hemisphere data are averaged only in the five latitude bands (0°-15°, 15°-30°, 30°-45°, 45°-60° and 60°-75°). First guess values beyond 75° latitude are extrapolated from the 45°-60° and 60°-75° latitude bands in winter. Thus, in winter the analyses are considered to be valid equatorward of 65°, but as the data become available poleward of 65° they are included and ultimately in summer the analysis is valid to 80°.

With an established first guess, the analysis uses four scans to successfully adjust the values at all gridpoints to nearby data. The technique is described by Yanai (1967) and is similar to that described by Cressman (1959). The four scans allow influence by data within 5, 4, 3 and 2 gridlengths of any gridpoint, respectively. If no data are found within any particular scan radius, the radius is increased one gridlength until at least one observation is found. Gridpoint adjustments are a function of the difference between data values and the first guess field interpolated (bilinearly) to the data location. (The interpolation is performed using the four gridpoints surrounding the data location.) The differences are multiplied by a weighting ratio, W, whose numerator is the difference of the squares of the maximum grid radius and the actual grid distance (between gridpoint and observation). The denominator is the sum of these squares. (See equation (1) below.) Weighted corrections are algebraically added, then averaged, and finally added to gridpoints. (See equation (2) below.) This process is applied for all 2397 points and four scans over each point.

$$W = \frac{M^2 - D^2}{M^2 + D^2} \tag{1}$$

: W = weight, $W \geq 0$ only
M = current maximum scan radius
D = distance between gridpoint and an observation

$$C_N = \frac{\Sigma\, W_i \times E_i}{\Sigma\, W_i} \tag{2}$$

: C_N = composite gridpoint correction for scan 'N'
W_i = weight for each observation (equation 1)
E_i = error (difference) between data and interpolation

Prior to final output, the analyses are smoothed with a routine using each gridpoint and the eight surrounding gridpoints. Smoothing is optionally cut off at latitudes greater than 60°. As an indication of the precision of the analyses, the root mean square differences of data minus analyses are less than about 5%. The final analysis output (on tape) consists of six 47 x 51 gridded fields in the same units originally specified for the input data.

An example of the output products is depicted in Figures 3 a-f, analyses for January 1-2, 1971. All analyses are archived on magnetic tape and will be available from the National Space Science Data Center at Goddard Space Flight Center.

Acknowledgment. This work was supported in part by the National Aeronautics and Space Administration, Goddard Space Flight Center.

REFERENCES

Cressman, G. P., 1959: An Operational Objective Analysis System, Monthly Weather Review, Vol. 87, No. 10, 367-374.

Heath, D. F., G. L. Mateer, and A. J. Krueger, 1973: The Nimbus-4 Backscatter Ultraviolet (BUV) Atmospheric Ozone Experiment--Two Years' Operation, Pure and Appl. Geoph., 106-108, 1238-1353.

Mateer, C. L., D. F. Heath, and A. J. Krueger, 1971: Estimation of Total Ozone from Satellite Measurements of Backscattered Ultraviolet Earth Radiance, J.A.S., 28, 1307-1311.

Yanai, M., 1964: An Experimental Objective Analysis in the Tropics, Technical Paper No. 62, Dept. of Atmos. Sci., Colorado State Univ.

TABLE 1

Ozone Analysis Products

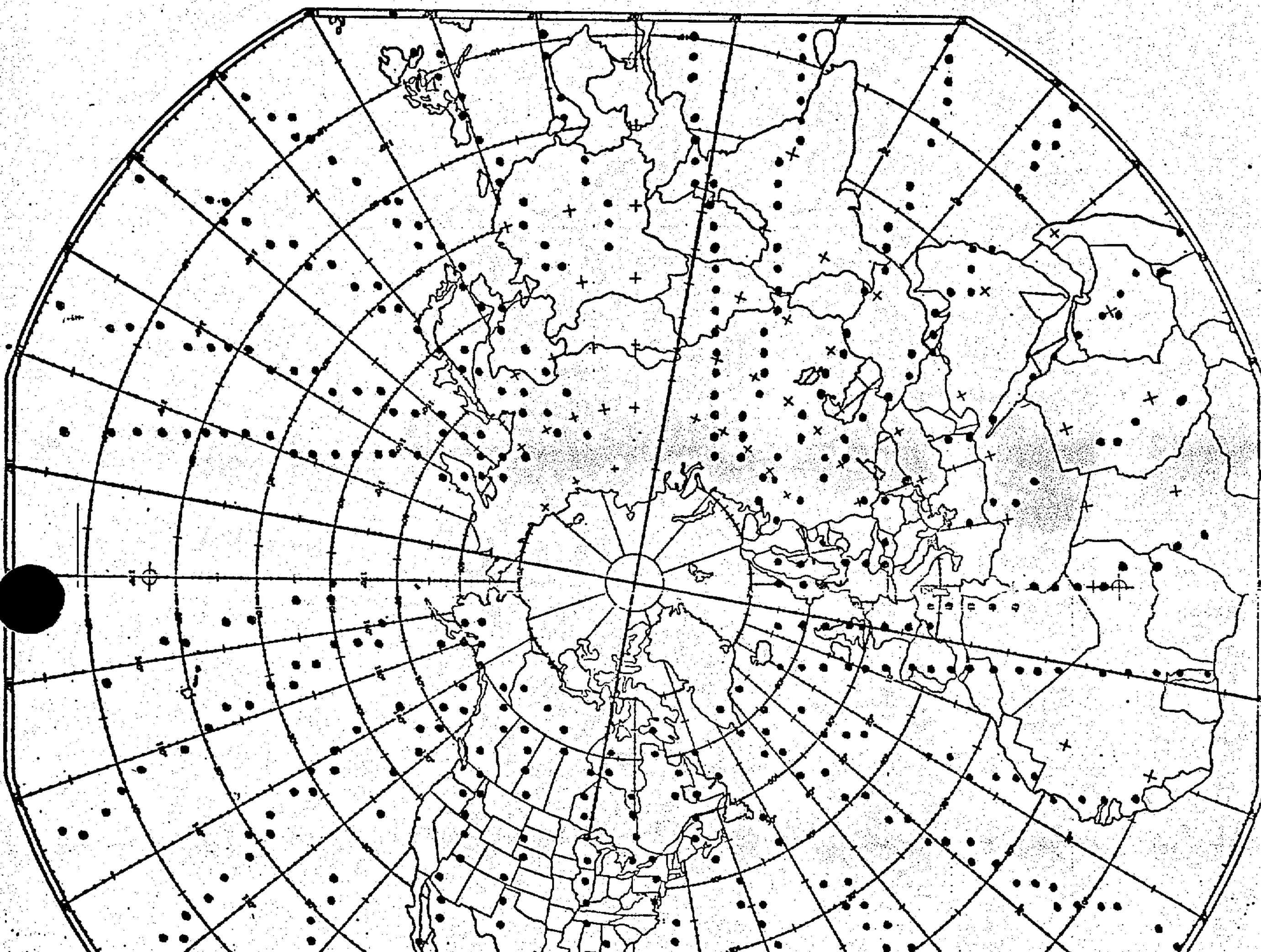
Total Ozone:

Northern Hemisphere

Southern Hemisphere

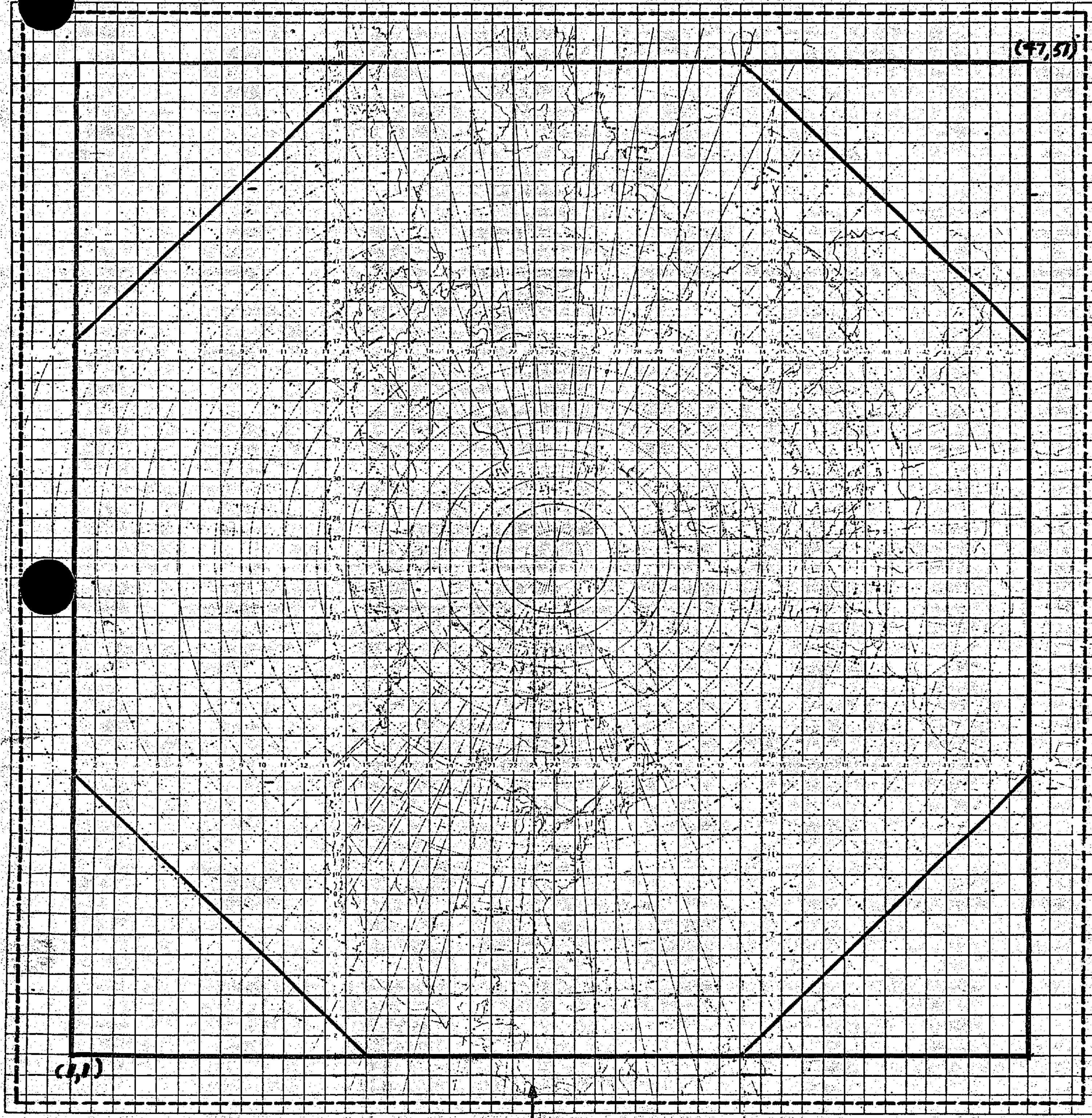
Ozone Mixing Ratio:

Northern Hemisphere at 30, 10, 5, 2, 0.4 mb



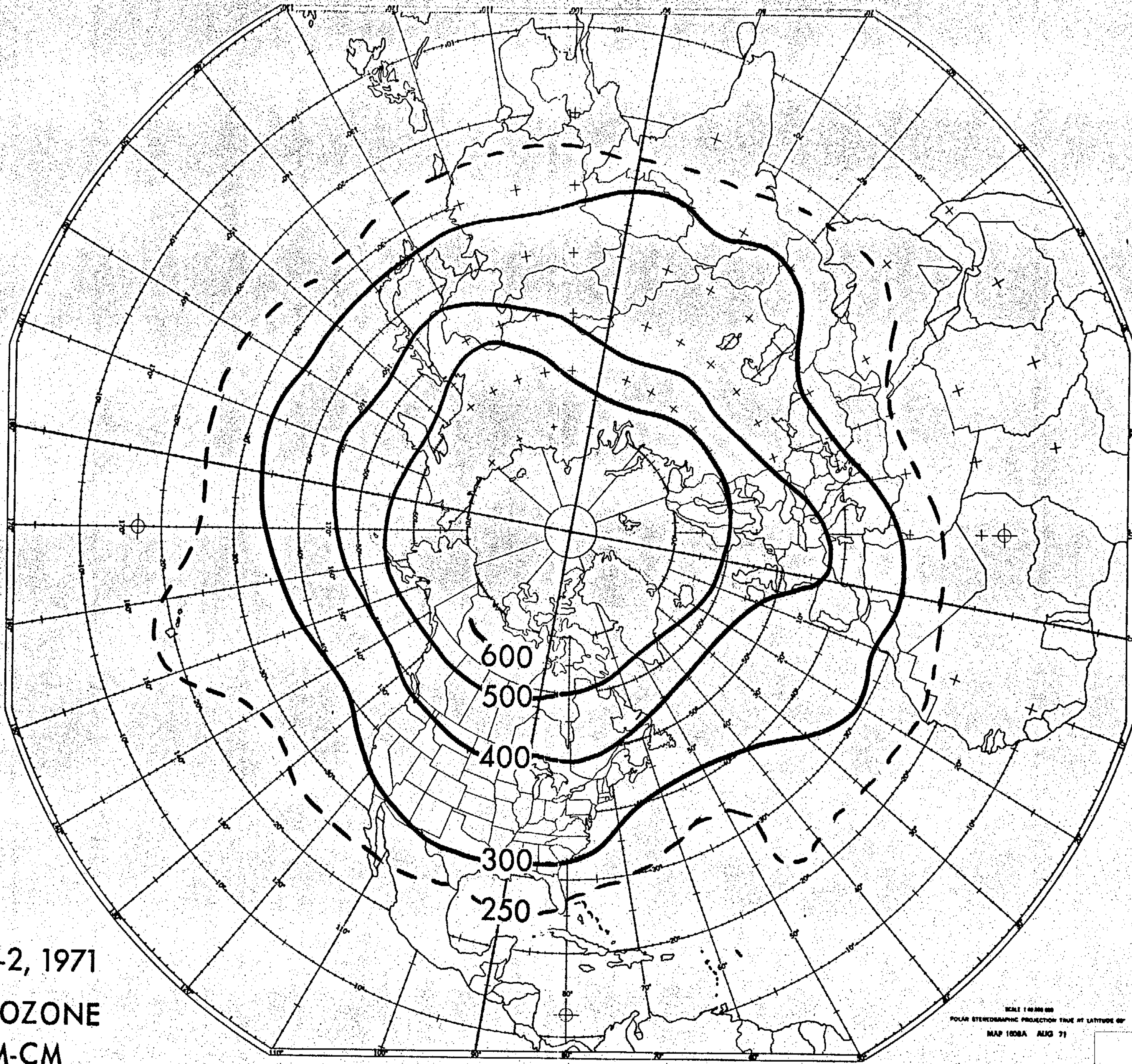
DEC. 11-12, 1970

FIGURE 1



47X51 OZONE ANALYSIS GRID

FIGURE 2

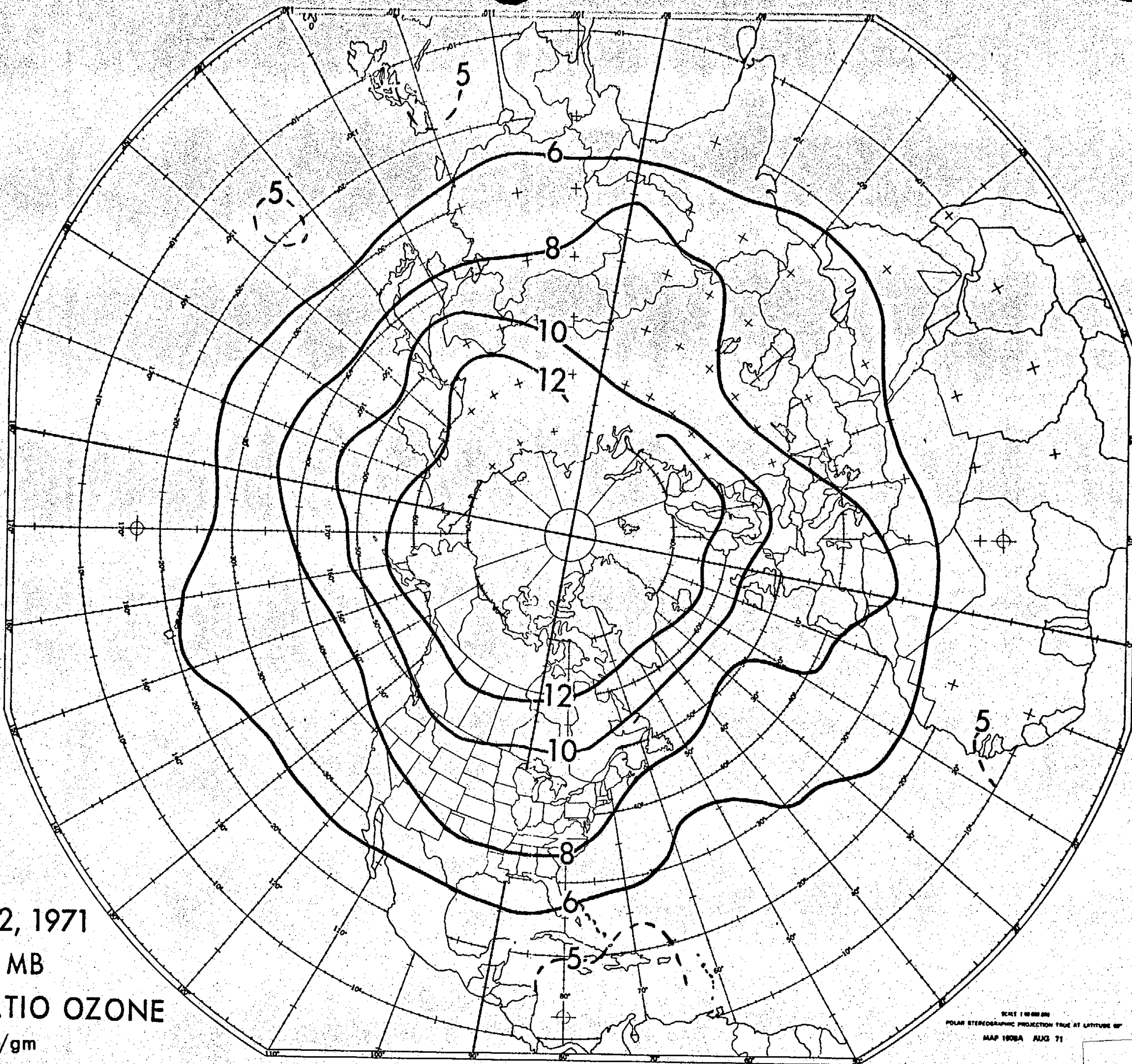


JAN. 1-2, 1971

TOTAL OZONE

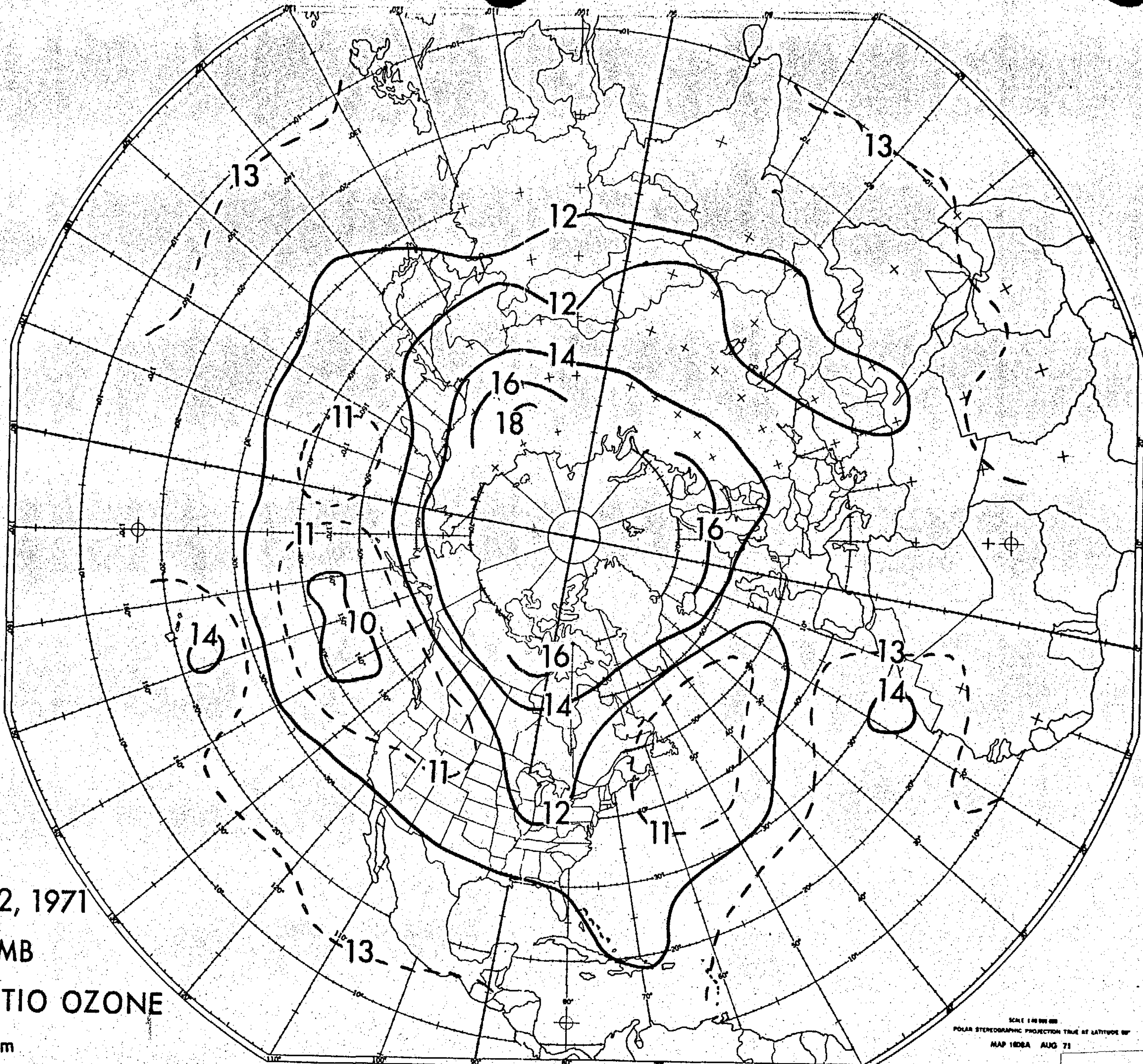
M-ATM-CM

FIGURE 3a



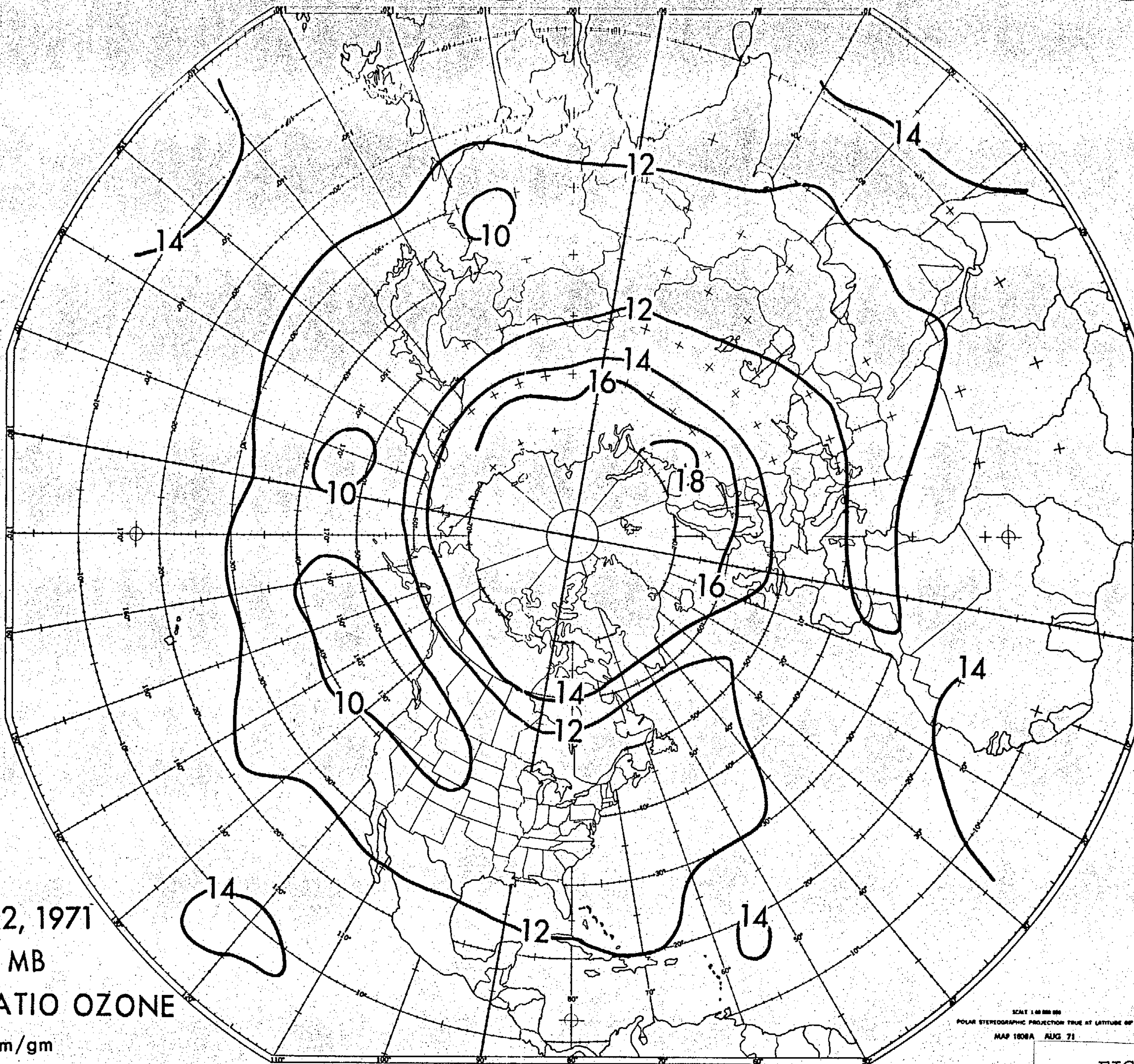
JAN. 1-2, 1971
30 MB
MIXING RATIO OZONE
μ gm/gm

FIGURE 3b



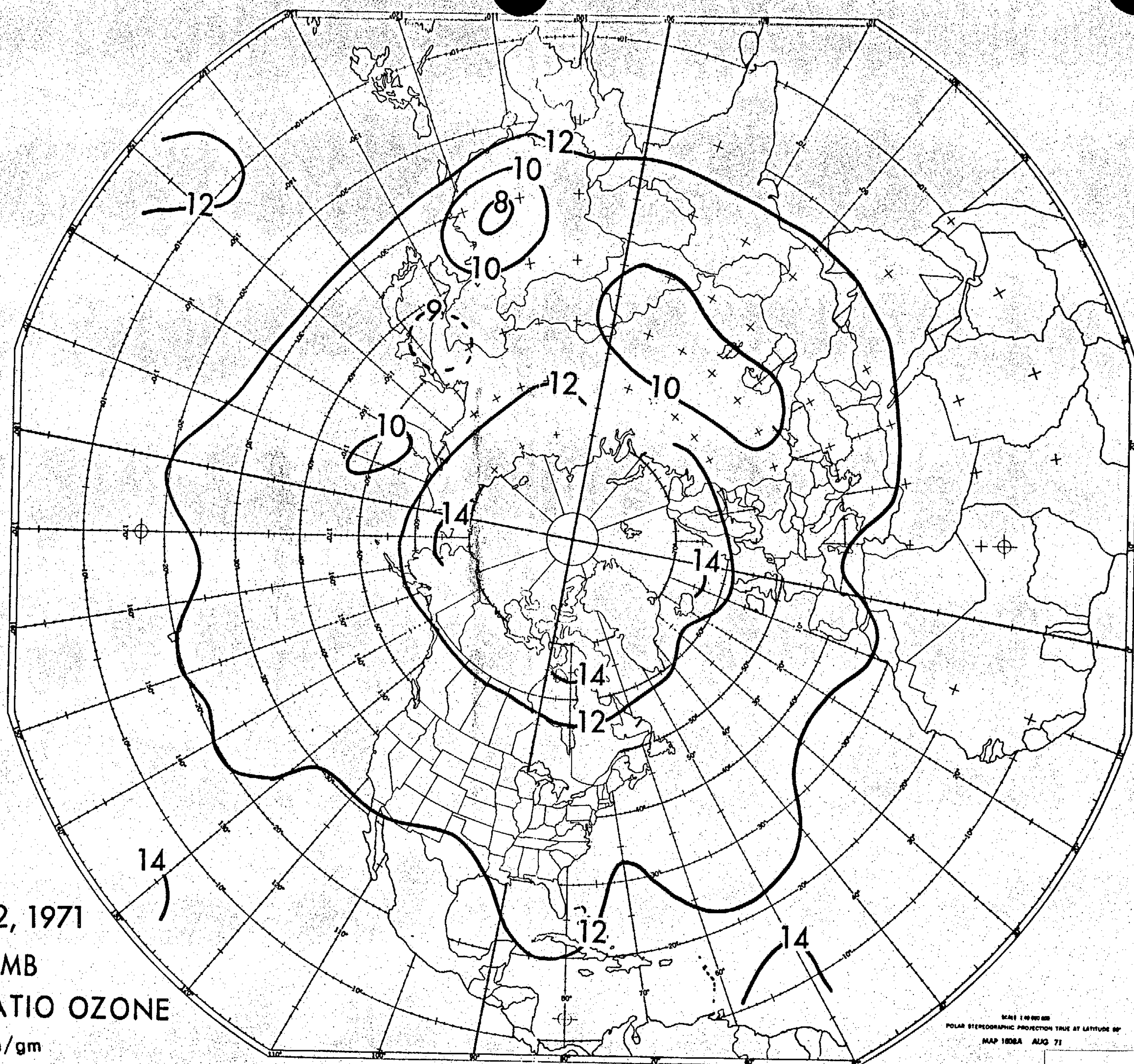
JAN. 1-2, 1971
10 MB
MIXING RATIO OZONE
μ gm/gm

FIGURE 3c



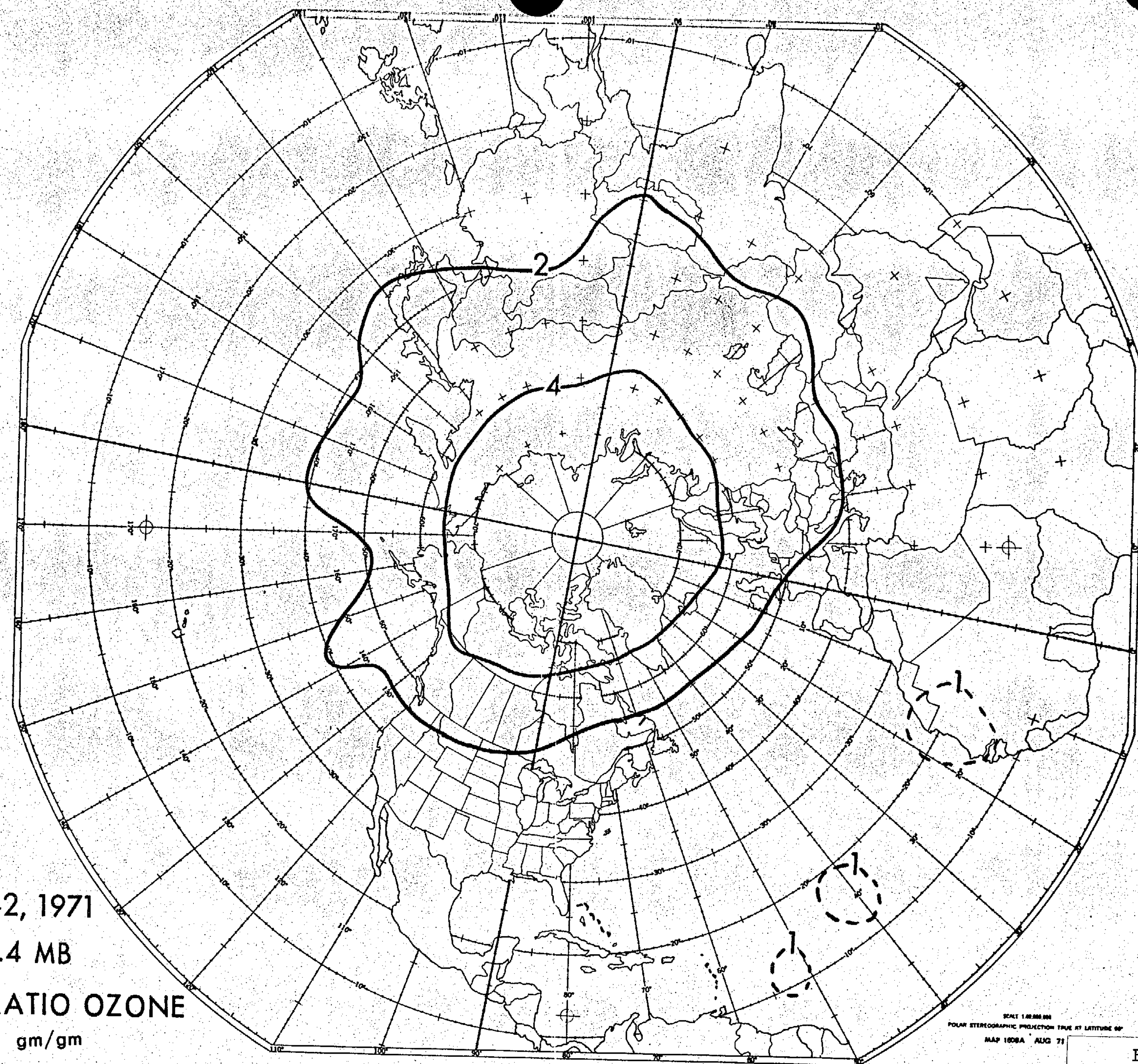
JAN. 1-2, 1971
5 MB
MIXING RATIO OZONE
μ gm/gm

FIGURE 3d



JAN. 1-2, 1971
2 MB
MIXING RATIO OZONE
μ gm/gm

FIGURE 3e



JAN. 1-2, 1971

0.4 MB

MIXING RATIO OZONE

μ gm/gm

FIGURE 3f